Proceedings of the 5th International Conference on Nonlinear Dynamics
ND-KhPI2016
September 27-30, 2016, Kharkov, Ukraine

Nonlinear Analysis of Gas Flow in Compressors Stage Based on CFD-Method

A. Karpik[1], Yu.Vorobiev[2]

Abstract
The numerical simulation of a three-dimensional viscous flow in cascade of the axial compressor of low pressure of the gas-turbine engine is presented. The results of a flow in the first stage of the compressor in non-stationary three-dimensional statement are obtained in the solver F. Velocity and pressure fields are received as a result.

Keywords
blade cascade, compressors stage, blade channel

[1] NTU «KhPI», Kharkiv
[2]IPMach, Kharkiv
*** Corresponding author:** karpikann@gmail.com

The flow in the compressor blade cascade can be unstable with a possible separation of a stream that lead to increase of vibrational load to the blades. An analysis of the unsteady flow physics permits to improve the overall aerodynamic and mechanical performance of turbomachine. Working blades of the compressor are affected by periodically changing gas forces. These forces are related to irregularity of an air-gas stream on a circle in air-gas channel of the engine. This irregularity is caused by the heterogeneity of the fields of velocity and pressure in front and behind of the working blades.

The problem of a non-stationary flow of blade cascade is described as the complex boundary-value problem. The flow in the blade channel is represented as nonlinear process; so, equations of the flow are nonlinear.

The fundamental equations of the gas dynamics are based on conservation laws of mass, momentum and energy. For a description of a spatial flow of gas in cascade of profiles the system of the nonlinear Navier-Stokes differential equations in partial derivatives is used. The most important properties, such as compressibility, viscosity, 3D effects, influence of radial gap flow, leakages etc., are included to the basic model.

Boundary conditions are assumed at the inlet as span-wise distribution of total pressure and total temperature; at the exit the span-wise distribution of static pressure is considered. Non-slip boundary conditions are assumed at the walls.

To solve the system of the equations the iterative differential scheme with use of sampling is constructed. The initial equations are integrated numerically by use of the iterative explicit and implicit differential scheme with a second order approximation. Explicit operator is based on the ENO scheme of Harten, and implicit approximation is realized by means of the scheme of Bim-Worming-Steger. Differential two-parametrical k-ω SST Menter's model is used as the model of turbulence. The scheme accuracy and grid refinement as well as an adequacy of a turbulence model influence are studied. The analysis of the scheme stability is done.

The numerical modeling of a three-dimensional viscous flow in blade cascade of the axial compressor of the low pressure gas-turbine engine based on CFD-method is carried out. CFD - method (Computational Fluid Dynamics) gives an insight into flow patterns that are expensive or impossible to study using experimental techniques. Numerical results on a flow in the first stage of the compressor, simulated as non-stationary three-dimensional problem, are obtained in the solver *F* [1]. The modeling is carried out on a differential H-grid with quantity of cells more than 1,3 million in one blade channel.

The periodical unsteady flow generated by the stator/rotor interaction in stage axial compressor is investigated. The changed distribution of gas flow which is presented on average section of the blade channel is discussed.

Numerical analysis is used to investigate the character of the secondary flow in a rotor including the interaction between secondary vortices and rotor wake. As a result, velocity and pressure fields are obtained; the main areas of non-uniformity of parameters are defined; areas of an adverse flow in the blade channel are revealed. The parameters of a flow in the grid profiles are estimated.

References

[1] Yershov S., Yakovlev V., Derevyanko A., Gryzun M., Kozyrets D. The development of new CFD solver for 3D turbomachinery flow computations. *Cieplne Maszyny Przepływowe. Turbomachinery*, Politechnika Łódzka, Łódź, Poland, 2012, No. 141, p.15-24.

[2] Yershov S., Rusanov A. Problems of numerical simulation of three-dimensional viscous flows in axial and centrifugal compressors. *Bulletin of Sumy State University*, 2005, No 1 (73), p.25- 34.

[3] Yershov S., Yakovlev V., Papazov S. Numerical modeling of a current in a compressor's cascade in the wide range of the modes of a flow. *Mechanical Engineering Problems*, 2014, No 4 (17), p.3-9.